The greatest precipitation in any one month was 16.46 inches, in July, 1875. Other large monthly amounts were 13.01 inches, July, 1896; 12.11, January, 1907; 11.43, January 1876; 10.53, August, 1888; and 10.02, August, 1879.

There is nothing to indicate any material change in the frequency of excessive rainfalls from one period to another. Thus, out of 80 cases, 24 occurred in the period 1872–1880, 14 in 1881–1890, 18 in 1891–1900, and 24 in 1900–1907. The slight apparent increase in the number in recent years is in some measure due to the introduction of recording gages; the float type of gage was introduced October 1, 1894, and the tipping-bucket type January 1, 1898.

A count of the cases in the individual years indicates a fair distribution, except that the last three years, 1905–1907, include 19 cases. This appears to be due to better methods of measurement during especially heavy periods of rainfall, and not to recurring cycles of excessive rainfall.

TABLE 1.—*Excessive rainfalls at Louisville, Ky., from January, 1872, to May 12, 1908.*

Month and year.	2.50 inches or more in 24 hours.		Excessive amounts for short periods.			Month and year.	2.50 inches or more in 24 hours.		Excessive amounts for short periods.		
	Amount.	Date.	Amount.	Time.	Date.		Amount.	Date.	Amount.	Time.	Date.
				Hr.m.						*Hr.m.*	
Jan., 1876	3.48	18				July, 1877	2.64	18			
Jan., 1898	2.55	22				July, 1892			2.00	1:50	3
Jan., 1907	3.23	2				July, 1894			1.00	1:00	19
Feb., 1880	2.51	13				July, 1896	5.50	4	2.70	1:00	4
Feb., 1882	2.97	20				July, 1896	4.19	20–21	1.29	1:00	21
Feb., 1883	2.68	6–7				July, 1897			1.39	1:00	10
Feb, 1908	2.70	4–5				July, 1901			1.13	0:30	3
Mar., 1890	2.51	10–11				July, 1906			0.59	0:30	27–28
Mar., 1897			0.50	0:15	23	July, 1907			0.63	0:20	9
Mar., 1898			1.19	1:00	16–17	July, 1907			0.79	0:30	15
Mar., 1908			0.62	0:25	31	July, 1907			0.55	0:15	18
Apr., 1872	3.56	8				Aug., 1878			0.63	0:15	19
Apr., 1880	4.06	15–16				Aug., 1879	2.97	15–16			
Apr., 1883	3.64	5–6				Aug., 1879	3.78	24–25			
Apr., 1887	3.28	22–23				Aug., 1882	3.27	24			
Apr., 1892	2.50	20–21				Aug., 1884	2.87	28–29			
May, 1872			0.99	0:40	25	Aug., 1888	2.87	20–21	0.54	0:30	1
May, 1873			1.34	0:50	1	Aug., 1891	2.82	2	2.50	2:00	2
May, 1878			1.30	1:05	27	Aug., 1898	3.68	8–9	2.66	1:23	8
May, 1880	3.89	29–30				Aug., 1905			0.60	0:15	7
May, 1889	2.99	29–30				Aug., 1905			1.00	0:46	23
May, 1902	3.53	22–23	1.08	1:00	23	Aug., 1907			0.54	0:20	20
May, 1903	2.97	31–1	1.05	0:15	81	Sept., 1879	2.99	2–3			
May, 1905	2.64	13–14				Sept., 1896	2.74	27–28			
May, 1906			0.83	0:18	31	Sept., 1905			0.65	0:20	1
May, 1906			0.66	0:25	4	Oct., 1876	4.12	29			
May, 1906			0.85	0:20	31	Oct., 1880	3.23	15			
May, 1908			0.67	0:20	6	Oct., 1883	3.34	28–29			
June, 1872	3.02	3				Oct., 1893	2.63	2–3			
June, 1878	2.92	17	0.95	0:37	27	Nov., 1878	2.81	26–27			
June, 1881			0.78	0:27	16	Nov., 1883	2.91	21–22			
June, 1890			1.22	1:00	15	Nov., 1900	3.16	20–21			
June, 1890			0.84	0:30	19	Nov., 1900	2.50	24–25			
June, 1895	2.66	19–20	0.51	0:05	4	Nov., 1905	2.81	28–29	1.00	0:46	28
June, 1896	2.87	22–23	1.00	0:10	23	Nov., 1906	2.85	17–18			
June, 1896			1.37	0:46	23	Nov., 1906	3.15	19–20			
June, 1901			1.25	1:00	20	Dec., 1873	3.87	3			
June, 1902			1.12	0:53	15	Dec., 1875	2.99	23–24			
June, 1905			0.48	0:15	7	Dec., 1879	3.07	23–24			
June, 1905			1.00	1:00	19	Dec., 1880	2.83	4			
July, 1875	2.97	11–12				Dec., 1905	2.86	1–2			
July, 1875	3.68	29									

TABLE 2.

NUMBER OF EXCESSIVE PERIODS OF RAINFALL.

1872	3	1881	1	1890	3	1899	0
1873	3	1882	2	1891	1	1900	2
1874	0	1883	4	1892	2	1901	2
1875	3	1884	1	1893	1	1902	2
1876	2	1885	0	1894	1	1903	1
1877	1	1886	0	1895	1	1904	0
1878	3	1887	1	1896	5	1905	8
1879	4	1888	1	1897	2	1906	6
1880	5	1889	1	1898	3	1907	5

RECAPITULATION BY MONTHS.

January	3	May	11	September	3
February	3	June	12	October	4
March	3	July	13	November	7
April	5	August	11	December	5

RECAPITULATION BY PERIODS.

1872–1880, inclusive	24	1891–1900, inclusive	18
1881–1890, inclusive	14	1901–1907, inclusive	24

A NEW FORMULA FOR COMPUTING THE SOLAR CONSTANT FROM PYRHELIOMETRIC OBSERVATIONS.

By H. H. KIMBALL.

[Read before the U. S. Weather Bureau Committee, April 29, 1908.]

An attempt has been made to develop an empirical formula by means of which the solar constant may be computed from pyrheliometric observations with an accuracy comparable with the accuracy of the observations themselves.

As suggested by Ångström,[1] if we express the coefficient of general atmospheric transmission for any wave length by the equation

$$y_\lambda = \varphi(\lambda) \qquad (1)$$

and the corresponding intensity of solar radiation by

$$I_\lambda = \Psi(\lambda) \qquad (2)$$

then the radiation received at the surface of the earth after the solar rays have past thru an atmospheric diffusing layer of thickness m will be exprest by

$$Q_m = \int_{\lambda_1}^{\lambda_2} \Psi(\lambda)\,[\varphi(\lambda)]^m\,d\lambda \qquad (3)$$

Since the function $\Psi(\lambda)$ is not exprest by any known law, the problem may be simplified by assuming a dispersion, x, that will give a solar spectrum of constant intensity. Such a dispersion has been computed from Abbot's values of the intensity of the normal solar spectrum outside the atmosphere.[2]

Equation (3) now takes the form—

$$Q_m = \int_{x_1}^{x_2} [\varphi(x)]^m\,dx \qquad (4)$$

TABLE 1.—*Vertical transmission of atmosphere.*

λ	x	Above Washington.		Above Mount Wilson.	
		Observed.	Computed.	Observed.	Computed.
0.387	0.0133	0.430	0.433	0.6844	0.6599
0.390	0.0171	0.445	0.454	0.6897	0.6754
0.3942	0.0245	0.499	0.482	0.7090	0.6981
0.3987	0.0334	0.535	0.510	0.7180	0.7183
0.4037	0.0435	0.553	0.533	0.7301	0.7360
0.4091	0.0541	0.564	0.555	0.7411	0.7509
0.4147	0.0641	0.575	0.572	0.7504	0.7627
0.4210	0.0751	0.587	0.588	0.7654	0.7739
0.4275	0.0866	0.594	0.603	0.7728	0.7841
0.4343	0.0987	0.611	0.617	0.7852	0.7936
0.4417	0.1122	0.631	0.631	0.7917	0.8030
0.4494	0.1267	0.639	0.645	6.8054	0.8120
0.4578	0.1427	0.647	0.659	0.8165	0.8210
0.4666	0.1595	0.666	0.672	0.8274	0.8294
0.4762	0.1777	0.674	0.685	0.8308	0.8377
0.4861	0.1962	0.689	0.697	0.8378	0.8454
0.4974	0.2144	0.702	0.708	0.8469	0.8523
0.5094	0.3252	0.710	0.720	0.8591	0.8596
0.5226	0.2576	0.717	0.732	0.8645	0.8668
0.5370	0.2818	0.725	0.743	0.8683	0.8740
0.5525	0.3073	0.740	0.755	0.8751	0.8810
0.5697	0.3346	0.745	0.766	0.8742	0.8879
0.5889	0.3641	0.751	0.778	0.8785	0.8948
0.6098	0.3948	0.768	0.789	0.8890	0.9015
0.6333	0.4280	0.791	0.800	0.9068	0.9082
0.6610	0.4636	0.815	0.812	0.9235	0.9149
0.6925	0.5013	0.835	0.823	0.9340	0.9216
0.7280	0.5408	0.850	0.834	0.9449	0.9280
0.7690	0.5819	0.860	0.845	0.9522	0.9343
0.818	0.6250	0.871	0.856	0.9588	0.9404
0.877	0.6707	0.883	0.867	0.9631	0.9466
0.946	0.7148	0.892	0.876	0.9675	0.9521
1.034	0.7610	0.906	0.886	0.9687	0.9576
1.127	0.8010	0.912	0.894	0.9706	0.9621
1.239	0.8407	0.915	0.902	0.9711	0.9664
1.367	0.8769	0.917	0.909	0.9746	0.9702
1.508	0.9082	0.923	0.914	0.9775	0.9733
1.648	0.9337	0.933	0.919	0.9756	0.9758
1.786	0.9545	0.926	0.922	0.9724	0.9778
1.924	0.9709	0.916	0.925	0.9800	0.9793
2.060	0.9817	0.904	0.927	0.9600	0.9803
2.196	0.9880	0.909	0.928	0.9740	0.9809
2.316	0.9919	0.894	0.929	0.9649	0.9812
2.428	0.9947	0.875	0.929	0.9251	0.9815

[1] Méthode nouvelle pour l'étude de la radiation solaire par Knut Ångström. Nova Acta Regiæ Societatis Scientiarum Upsaliensis. Ser. 4. Vol. 1, N. 7.

[2] Annals of the Astrophysical Observatory of the Smithsonian Institution. Vol. II, p. 105.

and equation (1) may be written

$$y_x = \varphi\,(x) \qquad (5)$$

In Table 1, "Vertical transmission of atmosphere," are given Abbot's values of atmospheric transmission above Mount Wilson and Washington,[3] and also the values of x computed for the different values of λ.

Assuming that $\varphi\,(x)$ has the exponential form, we may express (5) by

$$y_x = px^n \qquad (6)$$

Substituting for y_x the mean atmospheric transmission factors for Washington given in column 3 of Table 1, and solving equation (6) by the least-squares method, we obtain

$$y_x = 0.93x^{0.18} \qquad (7)$$

Similarly, substituting the mean atmospheric transmission above Mount Wilson given in column 5 of Table 1, we obtain

$$y_x = 0.98x^{0.09} \qquad (8)$$

The difference in the constants of these two equations is without doubt due to the difference in the general atmospheric absorption, viz, the scattering by the gas molecules and dust particles, above the two observing points. The transmission is the complement of the absorption, and Ångström suggests that we consider the general transmission as depending on the density of the atmospheric diffusing layer. Representing this density by δ, we may introduce this term in equation (6) as follows:

$$y_x = p^{\delta}\, x^{n\varphi(\delta)} \qquad (9)$$

Assuming that for the mean conditions at Washington $\delta = 1$, from equations (7) and (8), we find that for the mean conditions at Mount Wilson $\delta = 0.25$, and $\varphi\,(\delta) = \delta^{\frac{1}{2}}$.

Equations (7) and (8) may therefore be exprest by the general equation

$$y = 0.93^{\delta}\, x^{0.18\delta^{\frac{1}{2}}} \qquad (10)$$

In columns 4 and 6 of Table 1 are given the computed transmission coefficients when $\delta = 1$ and 0.25, respectively.

This equation therefore enables us to compute the general atmospheric transmission corresponding to any wave length and to densities of the diffusing atmospheric layer representing the mean conditions at Washington and at Mount Wilson. The equation is now to be tested to see if it is applicable to other values of δ.

For observations thru any air mass m equation (10) takes the form

$$y^m_x = 0.93^{m\delta}\, x^{0.18m\delta^{\frac{1}{2}}} \qquad (11)$$

Integrating this equation between the limits $x=0$ and $x=1$, and at the same time multiplying by the solar constant, since we have assumed the ordinate of our spectrum of constant intensity to be 1, we obtain

$$Q'_m = Q_0 \int_{x_0}^{x_1} 0.93^{m\delta}\,(x^{0.18m\delta^{\frac{1}{2}}})\,dx = Q_0 \frac{0.93^{m\delta}}{1+0.18\,m\delta^{\frac{1}{2}}}\,, \qquad (12)$$

where Q'_m = the total radiation that would be received at the surface of the earth after passing thru a diffusing atmospheric layer of thickness m and density δ, disregarding the losses due to such absorption by gases as is represented by the bands of the solar spectrum.

Abbot[4] states that the percentage of depletion of solar radiation due to absorption by water vapor above Mount Wilson may be exprest by the equation

$$F_w = 5.7 + 0.12\ E_w m \qquad (13)$$

and above Washington by

$$F_0 = 5.2 + 0.12\ E_0 m \qquad (14)$$

He also states that the difference between the first terms of the second members of these two equations is probably due to the fact that "Owing to the general absorption being greater above Washington than above Mount Wilson there is less radiation available to be absorbed by water vapor above Washington."

In other words,

$$F_0 = \varphi(\delta) + 0.12\ E_0 m \qquad (15)$$

where $E_0 = 2.3\ e_0$ represents the depth in millimeters to which the earth's surface would be covered by water if all the aqueous vapor were precipitated, e_0 representing the vapor pressure at sea level in millimeters.

Equation (15) takes the form

$$F_0 = (5.9 - 0.8\delta) + 0.12\ E_0 m \qquad (16)$$

Equation (16) does not allow for the slight band absorption by atmospheric gases other than water vapor. From an examination of bolograms made at the Astrophysical Observatory, Washington, this apparently amounts to only about 0.2 per cent of the solar radiation.

The total band absorption may, therefore, be exprest by

$$F_0' = (6.1 - 0.8\ \delta) + 0.12\ E_0 m \qquad (17)$$

Subtracting equation (17) from equation (12) we obtain

$$Q_m = Q_0 \frac{0.93^{m\delta}}{1 + 0.18m\delta^{\frac{1}{2}}} - \Big[(6.1 - 0.8\delta) + 0.12\,E_0 m.\Big] \qquad (18)$$

Equation (18) represents the total radiation received at the surface of the earth after the rays have been depleted both by general atmospheric absorption or scattering and also by selective gas absorption. From observations thru two air masses, as thru m and $m+1$, we obtain

$$\frac{Q_{m+1}}{Q_m} = \frac{\dfrac{0.93^{\delta(m+1)}}{1+0.18(m+1)\delta^{\frac{1}{2}}} - \Big[(6.1-0.8\delta)+0.12\ E_0(m+1)\Big]}{\dfrac{0.93^{\delta m}}{1+0.18m\delta^{\frac{1}{2}}} - \Big[(6.1-0.8\delta)+0.12\ E_0 m\Big]} \qquad (19)$$

from which δ may be computed. Having determined δ, the solar constant is found at once from equation (18) in the form

$$Q_0 = \frac{Q_m}{\dfrac{0.93^{\delta m}}{1+0.18m\delta^{\frac{1}{2}}} - \Big[(6.1-0.8\delta)+0.12\ E_0 m\Big]} \qquad (20)$$

Tables have been constructed giving the value of $\frac{Q_{m-1}}{Q_m}$ when $m=2$ for values of δ ranging from 0.20 to 2.20, and for values of e_0 ranging from 0.25 to 20 millimeters; and also giving the values of the denominator of the second member of equation (20) for the same limits of δ and e_0.

By means of these tables the value of the solar constant has been computed from observations made with the Ångström pyrheliometer at the Weather Bureau in Washington on 57 different occasions between December 22, 1905, and February 8, 1908, generally on different days, but occasionally in the morning and in the afternoon of the same day. The mean of these values is 2.004, or within 1 per cent of the value computed by Abbot from bolometric observations made at Mount Wilson.[5]

The highest value obtained was 2.247, on January 9, 1906, and the lowest value was 1.837, on November 15, 1907. On neither of these days were the meteorological conditions considered good. On only five occasions did the computed values of the solar constant fall below 1.90, and on only two occasions did they exceed 2.15. Under favorable conditions variations greater than 5 per cent from the mean have not been found.

[3] Ibid., p. 111 and 113.

[4] Ibid. p. 130.

[5] Ibid, pp. 96 and 97.

All pyrheliometric readings have been reduced to the Smithsonian Institution actinometric scale by means of the factors given in Table 6, Summary of Comparison of Pyrheliometers, Bulletin of the Mount Weather Observatory, Vol. I, part 2, p. 92.

TABLE 2.—*Comparison of computed values of the solar constant.*

Date.	Bolometric determinations.		Pyrheliometric determinations.
	Mount Wilson.	Astrophysical Observatory.	Weather Bureau.
1906.	*Solar constant.*	*Solar constant.*	*Solar constant.*
January 9	....	2.252	2.249
February 15	....	2.215	2.075
May 29	2.008	2.154	2.000
October 13	1.984		
October 15	....	....	2.006
October 16	2.043		
November 6	....	2.093	2.113
November 22	....	2.046	1.942
1907.			
February 15	....	1.972	2.006
May 13	....	2.119	2.035
Means	....	2.122	2.053

Table 2 gives comparisons between computations made by equation (20) from pyrheliometric observations obtained at the Weather Bureau in Washington, and bolometric determinations made by the Smithsonian Institution at the Astrophysical Observatory in Washington, and on Mount Wilson.[6]

These ten days are the only ones on which simultaneous observations were obtained, due to the fact that atmospheric conditions at Washington are unfavorable for pyrheliometric measurements during the summer months.

It will be noted that on May 29, and again in October, 1906, the agreement between the Weather Bureau pyrheliometric and the Mount Wilson bolometric determinations is very close. The agreement with the Washington bolometric determinations is not so good, but in most cases the cause is apparent and will be discust at another time.

A complete discussion of the pyrheliometric observations made by myself at Washington and by others at Mount Weather will appear in Bulletin of the Mount Weather Observatory, Vol. I, Part 4.

In my own observations the value of δ has ranged from 0.255 to 1.96, and the value of e_0 from 0.91 to 9.47. It therefore appears that the formula here developed enables us to compute the solar constant with a degree of accuracy comparable with that attainable with any apparatus at sea level, where the atmospheric conditions are too variable for highly accurate determinations.

The simplicity of the process should lead to its very general use in the reduction of pyrheliometric readings, and from the very many observations now being made in all parts of the world it should be easy to detect variations in the solar constant of 3 per cent or more if they occur.

The absolute value of the solar constant is dependent on the accuracy of the pyrheliometric scale employed. Unfortunately different types of pyrheliometers are not in accord; but by means of the data given in Table 6 of Vol. I, Part 2, Bulletin of the Mount Weather Observatory above referred to, it is believed that the relation between the Smithsonian actinometric scale and Ångström's pyrheliometric scale has been established. Comparisons between the Ångström and other types of instruments should now make it possible to establish the relations between all of the more important types of pyrheliometers in use, and thus make comparable the results obtained in all parts of the world. The need of an international pyrheliometric standard is, however, apparent.

[6] Ibid., 97-98.

NOTES FROM THE WEATHER BUREAU LIBRARY.

By C. FITZHUGH TALMAN, Assistant Librarian.

METEOROLOGY IN ROUMANIA.

Meteorologists will regret to learn that St. C. Hepites, who for so many years has been the official head of meteorology in Roumania, has severed his connection with the meteorological institute of that country, on account of a change in its affiliations recently decided upon by the Roumanian Government.

The Meteorological Institute of Roumania was founded by Hepites in 1884, and was attached to the Ministry of Agriculture, Industry, Commerce, and Domains. At that time, in addition to ten rainfall stations, there were but three places in Roumania at which meteorological observations were carried on. The number of stations is now over 400. In 1889 a metrological section was added to the institute. Seismology, also, has been cultivated in recent years. The results of observations have been published, in French and Roumanian, in a series of bulky yearbooks, besides other periodical and occasional publications in great number, and M. Hepites himself has been a most industrious writer upon the meteorology of his country.

Last year M. Hepites retired from the active directorship, in favor of M. I. St. Murat, and became honorary director, retaining charge of the purely scientific work. He has now left the institute altogether, on account of the transfer of the meteorological section to the astronomical observatory connected with the chair of astronomy at the University of Bukharest.

The section of weights and measures, of which M. Murat continues to be director, has been transferred to a newly organized Department of Industry and Commerce.

OBSERVATIONS BEGUN ON LAKE CONSTANCE.

Dr. E. Kleinschmidt, late assistant in the Meteorological Service of Alsace-Lorraine, at Strassburg, is in charge of the new kite station on Lake Constance, an account of which was published in the February MONTHLY WEATHER REVIEW, 1908, p. 21. This station began work April 1, and is now making observations every day, so far as conditions permit, with kites and captive balloons. The results are communicated daily to the Deutsche Seewarte, at Hamburg, and to the central meteorological stations of Bavaria, Württemberg, Baden, and Alsace-Lorraine, for utilization in connection with the daily weather forecasts.

CLIMATIC CHARTS OF CANADA.

The Weather Bureau has received a copy of the official Atlas of Canada, prepared by the government geographer, James White, and issued by the Canadian Department of the Interior. Although published in 1906, it appears to have escaped the attention of climatologists generally, until Petermanns Mitteilungen noticed it in the last annual summary of the literature of local climatology (54. Band, 1908, Heft 2).

Three plates of this atlas, viz, Nos. 25, 26, and 26A, are devoted to climate. The first gives isothermal charts for the twelve months of the year; the second comprises isotherms for the summer and for the year, precipitation and snowfall charts (annual) for southern Canada, and annual and quarterly isobars (the latter unfortunately referring to the quarters of the calendar year instead of the natural seasons); the third gives seasonal charts of the average possible hours of sunshine, and a series of charts showing the number of days in the year with mean temperature above 32°, 40°, 50°, 60°, and 70° F.

This is, we believe, the only extensive series of climatic charts yet issued for Canada.

THE SENSIBLE TEMPERATURE.

The much mooted question of the sensible temperature is discust by J. Vincent in a memoir entitled "Nouvelles recher-